moon's secular acceleration over and above the late determination. We have seen that the hypothesis of a retardation of the tidal wave by friction of only ten minutes is sufficient, according to Fourier's theory, of the loss of heat, and if we suppose the loss to be somewhat greater than this theory requires, it is only necessary to make the hypothesis a very little greater. If 6″ of the moon's secular acceleration is due to tidal action, then the length of the day has increased about $\frac{1}{140}$ of a second in the last twenty-five hundred years. If the effect of tidal action is insensible, and the late determination of the moon's secular acceleration from theory be received, then we have no way of accounting for the remaining 6″, and besides we cannot allow that the earth's volume has contracted as much as even Fourier's theory requires. The main point at which we have arrived is, that tidal action is adequate to account for 6″ of secular acceleration upon a very reasonable and probable hypothesis with regard to the magnitude and retardation of the tidal wave by friction, after making due allowance of the effect for counteracting the effect of a probable contraction of the earth's volume, and that we therefore have no just reason to reject the late determination of secular acceleration arising from a change of the eccentricity of the earth's orbit, because it does not cover the whole amount determined from the observations of ancient eclipses.

Professor Whitney read a paper on the progress of the Geological Survey of California, and presented to the Academy a volume of his report on the Paleontology of that State.

On the motion of Dr. H. R. Storer a committee was appointed, consisting of Professor Rogers, Dr. A. A. Gould, and Professor Agassiz, to consider what action the Academy should take toward promoting the Geological Survey of California and the adjacent territories.

Five hundred and forty-fourth Meeting.

January 10, 1865. — MONTHLY MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read letters relative to exchanges; also a communication from Mr. Otto Struve of the Observatory at Pulkova, announcing the decease of the eminent astronomer his father.

The following communication from Mr. E. W. Morley to Professor A. Hopkins of Williams College, was presented.

I have lately completed the reduction of my observations for the latitude of Williams College Observatory, and thinking you might like to have the result in some form which you can preserve, I transmit the final equations of condition with their solution. You will find the mode of observation fully described in Loomis's Practical Astronomy; briefly it is as follows. The telescope of the transit instrument being adjusted so as to move nearly in the plane of the prime vertical, the star's time of transiting the prime vertical is computed, together with its altitude at that time, and the transit pointed in readiness. The star moves transversely across the field, and is kept in the centre by moving the eyepiece horizontally and the telescope vertically. Its transits over the first ten wires are noted by the chronograph, the instrument is carefully reversed and the transits over the same wires in a reverse order are noted. After passing the meridian the transits over the same wires are noted again, and the instrument reversed as before. This gives forty passages to be noted, and, as a rule, ninety-six readings of the level. As the interval between the east and west passages is from three to five hours, there is but a small probability of getting a complete observation, and the loss of one of the four transits over each wire makes an observation valueless. Unfortunately, during the time I was occupied with the enclosed observations, the weather was so variable that a great proportion of my observations were lost, seven eighths or more I should think. The form of reduction is as follows. Take an observation of α Lyræ, July 19, 1861. Transit over wire (1).

	h.	m.	s.
East vertical, circle South	16	29	3.31
" " North	16	35	2.51
West vertical, circle North	20	28	26.00
" " South	20	34	23.57
W. — E., circle South	4	5	20.26
W. — E., circle North	3	53	23.49
$\frac{1}{4}$ Sum	1	59	40.94
$\frac{1}{4}$ Difference		2	59.19
Cos $\frac{1}{4}$ Sum	9.9378777		
Cos $\frac{1}{4}$ Difference	9.9999632		
Cotang d (declination)	0.0969342		
Cotang λ (latitude)	0.0347751		

	$\lambda =$	$42^\circ\ 42'\ 30''.73$
Correction for level		$+3.30$
" for azimuth		-0.35
" for declination		$+1.02$
	λ	$42\ 42\ 34.75$

The great part of my observations were lost by clouds, which would come up unexpectedly and spoil the labor of four hours, again and again. I have on some nights made as many as twenty observations, involving four hundred passages in the E. V., without getting a single star in the W. V., thus losing all. I can, therefore, rest the latitude of Williams College on only fifty-two observations, but hope these may be enough for present purposes.

Let $\lambda' =$ (latitude of P. V. instrument — $42^\circ\ 42'\ 20''$).

x be the value of one division of the level, which Mr. Phelps thinks to be near $1''.0$.

Values of $a\,\lambda' + a'\,x - b = 0$.

(A.) (*From Observation.*)

		Δ	Δ^2
1	$\lambda' + 5.39\,x - 20.88 =$	$-\ ''.92$	.8464
2	$\lambda' + 5.39\,x - 19.53 =$	$-\ 2.27$	5.1529
3	$\lambda' + 5.39\,x - 19.53 =$	$-\ 2.27$	5.1529
4	$\lambda' + 5.39\,x - 20.73 =$	$-\ 1.07$	1.1449
5	$\lambda' + 5.39\,x - 21.56 =$	$-\ .24$	.0576
6	$\lambda' + 5.39\,x - 21.09 =$	$-\ .71$	.5041
7	$\lambda' + 5.39\,x - 21.85 =$	$+\ .05$	.0025
8	$\lambda' + 5.39\,x - 22.27 =$	$+\ .47$	.2209
9	$\lambda' + 5.39\,x - 23.63 =$	$+\ 1.83$	3.3469
10	$\lambda' + 5.39\,x - 21.64 =$	$-\ .16$	.0256
11	$\lambda' + 5.38\,x - 21.85 =$	$+\ .06$	.0036
12	$\lambda' + 5.38\,x - 22.55 =$	$+\ .76$	.5776
13	$\lambda' + 5.38\,x - 20.73 =$	$-\ 1.06$	1.1236
14	$\lambda' + 5.38\,x - 21.40 =$	$-\ .39$	.1521
15	$\lambda' + 5.38\,x - 21.04 =$	$-\ .75$	.5625
16	$\lambda' + 5.38\,x - 22.06 =$	$+\ .27$	.0727
17	$\lambda' + 5.38\,x - 22.72 =$	$+\ .95$	.9025
18	$\lambda' + 5.38\,x - 23.02 =$	$+\ 1.23$	1.5129
19	$\lambda' + 5.38\,x - 22.63 =$	$+\ .84$	.7056
20	$\lambda' + 6.40\,x - 23.35 =$	$+\ .57$	.3249
21	$\lambda' + 6.40\,x - 23.16 =$	$+\ .38$	.1444
22	$\lambda' + 6.40\,x - 22.07 =$	$-\ .71$	.5041

		Δ	Δ²
23	$\lambda' + 6.40\,x - 22''.92 =$	$+\;''.14$	.0196
24	$\lambda' + 6.40\,x - 23.72 =$	$+\;.94$	.8836
25	$\lambda' + 6.40\,x - 23.21 =$	$+\;.43$	.1849
26	$\lambda' + 6.40\,x - 22.52 =$	$-\;.26$	.0676
27	$\lambda' + 6.40\,x - 24.87 =$	$+\;2.09$	4.3681
28	$\lambda' + 6.40\,x - 23.32 =$	$+\;.54$	.2916
29	$\lambda' + 6.40\,x - 23.22 =$	$+\;.44$	.1936
30	$\lambda' - 3.30\,x - 10.40 =$	$-\;1.95$	8.8025
31	$\lambda' - 3.30\,x - 11.09 =$	$-\;2.26$	5.1136
32	$\lambda' - 3.30\,x - 11.26 =$	$-\;2.09$	4.3681
33	$\lambda' - 3.30\,x - 10.25 =$	$-\;3.10$	9.6100
34	$\lambda' - 3.30\,x - 11.42 =$	$-\;1.93$	3.7249
35	$\lambda' - 3.30\,x - 10.95 =$	$-\;2.40$	5.7600
36	$\lambda' - 3.30\,x - 10.62 =$	$-\;2.73$	7.4529
37	$\lambda' - 3.30\,x - 11.12 =$	$-\;2.23$	4.9729
38	$\lambda' - 3.30\,x - 9.75 =$	$-\;3.60$	12.9600
39	$\lambda' - 3.30\,x - 11.69 =$	$-\;2.66$	7.0756
40	$\lambda' - 3.69\,x - 14.26 =$	$+\;1.29$	1.6641
41	$\lambda' - 3.69\,x - 14.37 =$	$+\;1.40$	1.9600
42	$\lambda' - 3.69\,x - 15.72 =$	$+\;2.75$	7.5625
43	$\lambda' - 3.69\,x - 15.93 =$	$+\;2.96$	8.7816
44	$\lambda' - 3.69\,x - 15.82 =$	$+\;2.85$	8.1225
45	$\lambda' - 3.69\,x - 15.34 =$	$+\;2.37$	5.6169
46	$\lambda' - 3.69\,x - 15.20 =$	$+\;2.23$	4.9729
47	$\lambda' - 3.69\,x - 15.26 =$	$+\;2.29$	5.2441
48	$\lambda' - 3.80\,x - 13.40 =$	$+\;.53$	.2809
49	$\lambda' - 3.80\,x - 15.15 =$	$+\;2.28$	5.1984
50	$\lambda' - 3.80\,x - 13.76 =$	$+\;.89$	.7921
51	$\lambda' - 3.80\,x - 13.95 =$	$+\;1.06$	1.1236
52	$\lambda' - 3.80\,x - 13.33 =$	$+\;.46$	.2116

(a.) $52\,\lambda' + 84.10\,x - 944''.11 = 0,\qquad \Sigma\,\Delta^2 = 145.4221.$

Values of $a'\,a\,\lambda' + a'^2\,x - a'\,b = 0$.

(B.)

1	$5.39\,\lambda'$	$+$	$29.05\,x$	$-$	112.54	$=$	0
2	$5.39\,\lambda'$	$+$	$29.05\,x$	$-$	105.27	$=$	0
3	$5.39\,\lambda'$	$+$	$29.05\,x$	$-$	105.27	$=$	0
4	$5.39\,\lambda'$	$+$	$29.05\,x$	$-$	111.73	$=$	0
5	$5.39\,\lambda'$	$+$	$29.05\,x$	$-$	116.21	$=$	0
6	$5.39\,\lambda'$	$+$	$29.05\,x$	$-$	113.68	$=$	0
7	$5.39\,\lambda'$	$+$	$29.05\,x$	$-$	117.77	$=$	0
8	$5.39\,\lambda'$	$+$	$29.05\,x$	$-$	120.03	$=$	0

9	+	5.39 λ'	+	29.05 x	—	130.37	=	0
10	+	5.39 λ'	+	29.05 x	—	116.64	=	0
11	+	5.38 λ'	+	29.05 x	—	117.55	=	0
12	+	5.38 λ'	+	28.94 x	—	121.32	=	0
13	+	5.38 λ'	+	28.94 x	—	111.53	=	0
14	+	5.38 λ'	+	28.94 x	—	115.13	=	0
15	+	5.38 λ'	+	28.94 x	—	113.39	=	0
16	+	5.38 λ'	+	28.94 x	—	118.68	=	0
17	+	5.38 λ'	+	28.94 x	—	122.23	=	0
18	+	5.38 λ'	+	28.94 x	—	123.85	=	0
19	+	5.38 λ'	+	28.94 x	—	121.75	=	0
20	+	6.40 λ'	+	40.96 x	—	149.44	=	0
21	+	6.40 λ'	+	40.96 x	—	148.42	=	0
22	+	6.40 λ'	+	40.96 x	—	141.25	=	0
23	+	6.40 λ'	+	40.96 x	—	146.69	=	0
24	+	6.40 λ'	+	40.96 x	—	151.81	=	0
25	+	6.40 λ'	+	40.96 x	—	148.54	=	0
26	+	6.40 λ'	+	40.96 x	—	144.13	=	0
27	+	6.40 λ'	+	40.96 x	—	159.17	=	0
28	+	6.40 λ'	+	40.96 x	—	149.25	=	0
29	+	6.40 λ'	+	40.96 x	—	148.61	=	0
30	—	3.30 λ'	+	10.89 x	+	37.62	=	0
31	—	3.30 λ'	+	10.89 x	+	36.60	=	0
32	—	3.30 λ'	+	10.89 x	+	37.16	=	0
33	—	3.30 λ'	+	10.89 x	+	33.83	=	0
34	—	3.30 λ'	+	10.89 x	+	37.69	=	0
35	—	3.30 λ'	+	10.89 x	+	36.14	=	0
36	—	3.30 λ'	+	10.89 x	+	35.05	=	0
37	—	3.30 λ'	+	10.89 x	+	36.70	=	0
38	—	3.30 λ'	+	10.89 x	+	32.18	=	0
39	—	3.30 λ'	+	10.89 x	+	38.57	=	0
40	—	3.69 λ'	+	13.62 x	+	52.62	=	0
41	—	3.69 λ'	+	13.62 x	+	54.03	=	0
42	—	3.69 λ'	+	13.62 x	+	58.01	=	0
43	—	3.69 λ'	+	13.62 x	+	58.78	=	0
44	—	3.69 λ'	+	13.62 x	+	58.38	=	0
45	—	3.69 λ'	+	13.62 x	+	56.60	=	0
46	—	3.69 λ'	+	13.62 x	+	56.09	=	0
47	—	3.69 λ'	+	13.62 x	+	56.21	=	0
48	—	3.80 λ'	+	14.44 x	+	50.92	=	0
49	—	3.80 λ'	+	14.44 x	+	57.57	=	0
50	—	3.80 λ'	+	14.44 x	+	52.29	=	0
51	—	3.80 λ'	+	14.44 x	+	53.01	=	0
52	—	3.80 λ'	+	14.44 x	+	50.65	=	0

(b.) $85.10\,\lambda' + 1250.65\,x - 2625''.55 = 0.$

(*a*) $52.00\,\lambda' + 85.10\,x - 944''.11 = 0,$

(*b*) $85.10\,\lambda' + 1250.65\,x - 2625''.55 = 0,$

log 1250.65	3.0971358		-13874.87
log 85.10	1.9299296		$+2625.55$
log (*a*)	1.1672062		-11249.32
log 52	1.7160035		$1250.65\,x$
log 52 + log (*a*)	2.8832095	764.20	$-1250.65\,x$
			$0.0\,x$
log 944.11	2.9750226		
log (944.11 × *a*)	4.1422288	13874.87	$+764.20\,\lambda'$
			$-85.10\,\lambda'$

Hence, $764''.20\,\lambda' + 1250''.65\,x - 13874''.87 = 0 + 679''.10\,\lambda'$

$679.10\,\lambda' - 11249.32 = 0.$

log 11249″.32	4.0511263		
log 679″.10	2.8319337		
log λ'	1.2191926	$\lambda' = 16''.56$	(1)

log 85″.10	1.9299296		
log (85″.10 λ')	3.1491222	1409″.80	$-1409''.80$
			2625″.55
log 1215″.75	3.0848452		1215″.75
log 1250″.65 (*x*)	3.0971358		
log (*x*)	9.9877064	$x = 0''.9721$	(2)

$\Sigma\,\Delta^2 = 145.4221,\qquad \frac{\Sigma\,\Delta^2}{52} = 2.603$

log 2.603	0.4156910		
log $(2.603)^{\frac{1}{2}}$	0.2078455		
log constant	9.8289751	Probable error of single	
log prob. error	0.0368206	observation $\pm$ 1″.0885	(3)

log $(2.603)^{\frac{1}{2}}$	0.20785		
log constant	9.60091		
log mean error	9.80876	Mean error 0″.644	(4)

$\log\left(\frac{2\,\Sigma\,\Delta^2}{n}\right)$	0.71650		
log reciprocal	9.28350	Precision .1921	(5)
log $\sqrt{}$ reciprocal	9.64175	Weight .4383	(6)

$$\frac{\Sigma\,\Delta^2}{52-2} = e^2 = 2.908442$$

$\log e^2$	0.463660	
$\log \chi^2$	0.825686	Table in Coast Survey Report,
$\log \chi^2 e^2$	1.289346	1854, p. 136.*
$\log \chi e$	.644673	
χe	$\pm$ 4″.412	Limit by Peirce's Criterion. (7)

$\Sigma\, a^2 = 52$ $\quad \Sigma\, a'^2 = 1250.65$ $\quad \Sigma\, a\, a' = 85.10$

$(\Sigma\, a\, a')^2 = 7242.01$ $\quad c = \Sigma\, a^2 \cdot \Sigma\, a'^2 - (\Sigma\, a\, a')^2 = 57791.79.$

	λ'.		x.
$\log \Sigma\, a'^2$	3.096118	$\log \Sigma\, a^2$	1.71600
$\log c$	4.761868		4.76187
$\log d^2$	8.334250	$\log d'^2$	6.95413
$\log d$	9.167125	$\log d'$	8.47706
log mean error	9.80876		9.80876
log mean error of result	8.97589		8.28582
	Mean error λ' 0″.0946 (8)		Mean error x 0″.0193 (9)
log constant	0.22807		0.22807
log prob. error of result	9.20396		8.51389
	Probable error λ' 0″.1599 (10)		Prob. error x 0″.0327 (11)

(A) are the fifty-two observations. Each equation should be $= 0$, the quantities in the column Δ are the errors of each observation. The column Δ^2 contains the squares of these errors, and the values of λ' and x are those which make $\Sigma\,\Delta^2$ (the sum of the squares of the errors) a minimum, and are, therefore, the *most probable* values. (3) gives the quantity 1″.0885, as the probable error of a single observation. (7) gives 4″.41 as the limit, by Peirce's Criterion, for a doubtful observation. (10) gives, as the probable error of the resulting latitude, 0″.16. It is more likely than not that the result is within this amount of the truth. The common tables will show that it is 100 to 1 that my latitude is within 0″.61; 200 to 1 that it is within 0″.67; and 300 to 1 that it is within 0″.78 of the truth.

The prime vertical transit was one hundred feet south of the centre of the dome, which is 1″.0 of arc, which is to be added to my result. α Lyræ's place was taken from the English Nautical Almanac. Its declination (d) is 1″.0 different in the American, and 0″.1 *less* in the

Berlin Jahrbuch. To reduce to either of these authorities, the variation of the declination (δd) must be multiplied into 1.02. When all terms are taken into account, the latitude is

$$\lambda = 42^\circ\ 42'\ 20'' + 16''.56 + 1''.0 + 1.02\ \delta d \pm 0''.1599,$$

from which for use,

$$\lambda = 42^\circ\ 42'\ 37''.56 \qquad \text{or,} \qquad 42^\circ : 42' : 37''.6 :$$

The value of one division of the level is $0''.972 \pm ''.033$.

Five hundred and forty-fifth Meeting.

January 25, 1865.— STATUTE MEETING.

The PRESIDENT in the chair.

The President called the attention of the Academy to the recent decease of two of its members,— Hon. Edward Everett and Mr. W. P. G. Bartlett, of the Resident Fellows.

Professor Henry D. Rogers, of Glasgow, was elected an Associate Fellow in Class II. Section 1.

Mr. Frederick W. Putnam, of Salem, was elected a Resident Fellow in Class II. Section 3.

Five hundred and forty-sixth Meeting.

February 14, 1865.— MONTHLY MEETING.

The PRESIDENT in the chair.

The President called the attention of the Academy to the recent decease of Capt. J. M. Gilliss, an Associate Fellow, and the Director of the National Observatory at Washington.

Mr. Ferrel made the following communication:—

"It was shown in a note read on a former occasion, that if the tidal wave of the ocean is on an average two feet high and displaced two degrees by friction, the effect of the moon's attraction on the tidal wave must cause an increase of $\frac{1}{140}$ of a second in the length of the day in 2,500 years. From this we may readily determine that the earth's